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Aspects of Water Quality and Water Pollution Control in Vulnerable Environments

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Abstract

Water quality relates to set standards of compliance for various uses. Challenges of water pollution are critical in vulnerable hydrological systems undergoing degradation, population pressure and land use changes. Water quality can be improved by applying technological innovations and sustainable watershed management practices. Stakeholder involvement and environmental stewardship are essential to equitable water use and governance for collective actions that benefit people and nature.

Introduction

Water quality pertains to the physical, chemical and biological characteristics of water often used with reference to set standards of compliance. Agencies set standards based on political and technical decisions about water use with different uses raising different concerns. Natural water bodies vary in response to environmental conditions. Water has to be maintained at quality commensurate with its identified use. Water pollution is largely due to industry, runoff from agricultural areas, urban stormwater runoff and discharge of treated and untreated sewage. The parameters for water quality are determined by the intended use and different countries have agencies that deal with standards for various uses, e.g the U.S. Environmental Protection Agency (EPA) in the US limits the amounts of certain contaminants in tap water through Safe Drinking Water Act to ensure human health.Some water quality laws also specify protection of fisheries and recreational use and require certain minimum quality standards.

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There are monitoring programs of water quality conducted by government agencies to track the compliance using the various parameters such as pH, fecal coliform bacteria (*Escherichia coli*), Biochemical oxygen demand (BOD) Temperature, Total suspended solids (TSS) and Turbidity. The water policy of the European Union is primarily codified in three directives: The Urban Waste Water Treatment Directive (91/271/EEC) of 21st May 1991 concerning discharges of municipal and some industrial waste waters; The Drinking Water Directive (98/83/EC) of 3rd November 1998 concerning potable water quality; and Water Framework Directive (2000/60/EC) of 23rd October 2000 concerning water resources management. Water quality guidelines for South Africa are grouped according to potential user types (e.g. domestic, industrial) in the 1996 Water Quality Guidelines. Drinking water quality is subject to the South African National Standard (SANS) 241 Drinking Water Specification.

High rate of population growth is causing increases in waste water volumes jeorpadising the integrity of river basins. The increasing population is also posing degradation and land use changes and unsustainable resource utilization, increasing demand for more food, water and energy. The interaction between human activities and climate, trends in atmospheric concentration of human induced green house gases and the biological, environmental, economical activities have implications on water quality.The problems of water pollution, approaches to pollution studies for Kenyan examples and reflections of underlying challenges are discussed.

Problems and impacts of water pollution

Water quality problems are rampant in hydrological systems worldwide: river basins, aquifers, lakes, estuaries and seas and impact the uses to which water can be put. Sea level rises as a consequence of global warming put low lying areas in serious water quality problems. The waste removal capacities of rivers and wetlands has dwindled and dilution is no longer the solution to pollution. Most of the water quality problems are revealed in the impacts they cause, especially in the vulnerable environments; lakes, degrading wetlands, arid and semi arid watersheds and coastal environments the world over. Some world fresh water lakes such as Lake Titicaca in South America suffer from urban and agricultural pollution. Climate change also threatens to melt the glaciers that provide much of the lake's water. Most of the cities through which the major rivers flow before draining into the lake; have poor sewer systems takes a toll on the lake. In early 2015, the Peruvian government announced it would spend $ US 450 m to build waste water treatment plants to stem the flow of sewage into the lake. Infact, many lakes across continents suffer threats of pollution, climate change, declining water levels, or declining fish stocks. These threats inhibit their ability to supply water, drive economic activities, preserve biodiversity, and sustain communities.

About 75% of the African continent is ASAL and is prone to drought vagaries. The water access problem stems from a combination of over use, poor management and adverse climatic conditions.

The per capita water supply in Africa has declined by more than 50% since the last century due to the growing demand in agriculture which forms the backbone of the income and livelihoods for the rural populations. In the export markets for tea, coffee, sugar and flowers, there is extensive use of fertilizers and pesticides with potential to harm the water quality in hydrological systems. Agricultural runoff is the major non-point source of pollutants including sediments, phosphorus, nitrogen and pecticides.

In the river basins, the water management strategies need to consider upstream/downstream demand and supply management. Suitable technologies for local conditions in Africa are mandatory to ensure sustainable environmental and water quality for socio economic uses. The use of drip irrigation for example would reduce the likelihood of both salinization and pollution from runoff. Declining water quality can be attributed to over pumping especially in coastal aquifers, runoff from agriculture, discharge of human and industrial waste and loss of habitat. A decline in water table can have adverse effects including additional pumping costs, overuse of energy, low water quality flowing inwards and contamination of the fresh water of aquifers as well as salt water intrusion.

Growing cities require increasing water supplies and sewer systems. The discharge of untreated waste water into rivers is risky. Damping of industrial wastes directly to water courses and that by rainfall and runoff over stretches may seep into aquifers. A water secure future requires proper management of rural and urban effluents and agrochemicals carried by runoff. Agroprocessing industries such as coffee pulping, paper mills, sugar processing and other effluent discharges must be controlled to avoid high BODs and algal blooms.

Efforts and approaches to sustain water sanitation and hygine systems and services in Africa as well as investigation of water security for growth and climate resilience are desirable. Monitoring the current water quality in the hydrological systems and how it is changing over time with respect to human activities will enable improved understanding for more efficient water resource use in agriculture and access to safe water.The effect of pollution on aquatic systems largely depend on whether polluted waters are standing or flowing with standing systems being more vulnerable.The major water pollutants are organic and inorganic nutrients, sediment and heat.

The oganic nutrients coming from feedlots, municipal sewage treatment plants, and industry promote growth of aquatic bacteria whose decomposition results in declines in dissolved oxygen.The inorganic plant nutrients, nitrogen and phosphorus coming from septic tanks, heavily fertilized crops, and sewage treatment plants, cause excessive plant growth and the drop of dissolved oxygen.

Other toxic organic pollutants are pesticides and PCBs, many of which are nonbiodegradable. Sediments as byproduct of erosion result from poor agricultural practices, mining and construction. The major groundwater pollutants are chlorides, nitrates, heavy metals, and toxic organics. Since groundwater usually moves slowly through an aquifer, it may take years for pollution to show up in areas adjacent to sources of contamination and once an aquifer is contaminated the pollutants may remain for long. The oceans receive pollutants from many sources such as oil spills and inputs from polluted rivers. The plastic pollution garbage, and medical wastes can kill marine life. Water quality monitoring requires collection of samples with a uniform frequency at fixed stations; the network of stations being based on certain objectives. These could be carried out on lakes, rivers or on land with sampling frequency being based on water level fluctuations for different seasons.

Eutrophication occurs as the result of anthropogenic pollution with nutrients, particularly the release of sewage effluent and agricultural run-off carrying fertilizers into natural waters. It has the effect of decreasing resource value of rivers, lakes, and estuaries.Phosphorus is often associated with eutrophication in lakes subjected to point source pollution from sewage. Dissolved Oxygen (DO) concentrations are often measured in estuarine environments to quantify the result of and stresses associated with eutrophication. These vary greatly with time of day and typical monitoring programs must capture these variations.

Water purification processes such as dilution, filtration, sedimentation, acid base reactions and pH buffering, precipitation and dissolution, coagulation and chemical sorption, hydrolysis and plant uptake all occur naturally in river and wetland systems. When properly quantified, they may be used as effective tools in management of water quality. Management actions that seek to preserve and even enhance these processes can be sought in watershed management plans. These may be conservation and restoration oriented. They may also be procedural such as monitoring the degree of flow variability in highly regulated river regimes. The focus is to conserve and restore the integrity of aquatic systems within overall plan that is consistent with development goals of a given river basin. The geographical location, climate and socio-politics reflecting diffeeent levels of pollution would require best practices for sustainable development devoid of pollution impacts.

Approaches to water pollution studies: some examples from Kenya

Fluospar mining and disposal of mine waste influence surface and ground water quality in the Kerio Valley area. Several hydrochemical parameters and their interrelationships have been determined in order to identify pollution types and transport mechanisms. Adsorption and complex formation were shown to be important processes governing the behavior of metals in the waters. The dissolved metal fraction was consequently low and of limited toxicological significance.

The levels of nutrients such as nitrates and phosphates were within acceptable limits in relation to quality of ecosystems these waters can sustain. Because of the relatively high erosion rates and leaching of associated bedrock, exegerated values were found for dissolved solids, electrical conductivity and alkaninity. Indices of organic pollution such as biochemical oxygen demand (BOD) were upto ten times their maximum permissible limits for domestic water supply. Organic pollutants were attributed to reagents used for ore processing.

The water quality of Sosiani catchment was investigated by (Ontumbi *et al*, 2015). The spatial temporal variation of the physico-chemical variables of water quality were analyzed for water samples collected in the dry and wet seasons for selected sites identified by Landsat images reflecting upstream agricultural activities. The river was shown to be polluted by nutrients from upstream agricultural activities. Further, the water quality variation also examined spatio temporal variations of faecal coliforms in water samples to identify water borne diseases in the catchment. The dry season faecal coliform counts were less than the wet season values. Kelsey *et al* (2004) had revealed a relationship between land use and fecal coliform bacteria pollution with proximity to areas with septic tanks or more urbanized land uses tending to have higher fecal coliform densities. Major sources of pollution in the catchment area include the human households and municipal wastes from business premises, market, hospital and learning institutions with no proper dumping sites in the area. An ongoing study seeks to apply the DIPSIR conceptual framework to investigate the practices directly related to the quality of water in the River Nzoia watershed in the paper manufacturing industry in Webuye area.

The Nairobi River in the Upper Athi basin is getting degraded and polluted by sewage and industrial effluents as well as dump sites in some locations with potential for ground water pollution as well. In open dumps, rain water moves through the refuse and absorbs any organic and inorganic compounds including metals, pesticides, and solvents that are in the refuse thereby producing leachate which may eventually enter the ground water. A study on leachate based on soil samples on some damp sites showed a decrease of conductivity, turbidity, Chemical Oxygen Demand and nitrates with an increase in depth.

Alkalinity, chlorides, pH and DO were also found to increase with depth. Another study using physico-chemical and microbial characteristics has shown the limitations of water quality for the ground water use. The groundwater quality map developed using a Water Quality Index (WQI) indicated poor water quality to be attributed to poor watershed management and use of inappropriate techniques and infrastructure by the Nairobi peri urban communities. The environmental deterioration due to waste damping and poor disposal of solid and liquid waste has also been evidenced during the flood events in other areas within the country which threatens the water supply systems.

Most urban centers do not have adequate drainage and sewerage systems and degrading of watersheds by poor land use practices contribute to sedimentation and pollution that undermine environmental integrity. The flow in streams is also affected by intensified agriculture, municipal and industrial effluents as well as urbanization and poor water abstractions. Some of the water supply sources seeking to satisfy the increasing needs such as springs, shallow wells, streams and roof catchment rain water harvesting are prone to contamination posing health risks from water borne diseases.

Model applications in water resource management have revealed the impact of rapid population, agricultural practices and industrial effluents. Of significance is the Lake Victoria Basin where agricultural practices reflected in the growing of rice and sugarcane with respective industrial processing have impacted the water quality.The activities in the basin including the mushrooming urban centers have increased the demand of water for domestic use, food and industrial development thereby creating competition and significant water quality impacts. To accommodate the competing water demands, ongoing studies are utilizing the water allocating model, WEAP, in simulating and predicting the effect of water allocation scenarios and possible management options. The water quality problems could be controlled by assigning allowable discharges to water bodies for designated water use and quality standards to be met.

In Gucha watershed within the Lake Victoria basin, Ongwenyi *et al* (1993) reported presence of saline ammonia indicative of organic pollution that may have emanated from slaughter houses and agricultural effluents from coffee and tea factories. A study by LVEMP (1995) showed the influence of increased settlements, ground water recharge and degradation from the erosion processes as influencing the variation of river water quality following fluctuations of river discharge. During floods, the water quality was determined by the origin of runoff, for example the agro-based industries, urban centers and agricultural practices in catchments.

There was distinctive variability of pollution loadings to the lake from Nyando and Gucha (LVEMP, 1995), the major water pollutants being organic nutrients, inorganic nutrients (nitrogen and phosphorus) from fertilizer applications and sewage treatment plants and sediments. The lake suffers pollution from both point and non-point sources. Gathenya *et al* (2014) have highlighted the need for responsible water stewardship for governance of Lake Naivasha within the Kenya Rift Valley where growing populations and economies, changing lifestyles, and global climate change are putting pressure on the water resources. The world's water users ranging from agriculture, energy, industry to urban and rural uses recognize the need to manage the water resources. Organizations and stakeholders are aware of the need for environmental management for sustainable growth and development (ISO 1400).

By 2030, 47% of the world's population will be living in areas of high water stress (UN, 2012). Through water medium, major global crises of food, energy, health and climate change, as well as economic crises can be jointly addressed. Explicit trade-offs may need to be made to allocate water to uses which maximize achievable benefits across a number of developmental sectors. Protecting water resources, optimizing their use across these activities, and ensuring an equitable distribution of benefits from water-intensive activities should be at the centre of public policy and regulation. The Lake Naivasha Basin in Kenya is a unique natural, social and business environment hosting more than 70 % of the country's cut flower business, geothermal power generation, tourism, fishing, pastoralism, small holder agriculture and an expanding municipality (Hepworth, *et al.,* 2011).

There is concern on the lake's environmental integrity to be maintained while still supporting a valuable and growing economy and society (WWF, 2012). The three approaches to enhance water governance in a watershed include; enforcing existing laws on water resources management, giving incentives to land owners for actions that contribute to improved water resources management and; promoting voluntary standards where subscribing farmers are required to apply agricultural management practices that are beneficial to water resources in return for other benefits such as better markets for their products. In this connection the Alliance for Water Stewardship has developed an international standard that promotes responsible water stewardship. Water stewardship is the use of water that is socially equitable, environmentally sustainable and economically beneficial. It is achieved through a stakeholder-inclusive process that involves site and catchment-based actions. Good water stewards are individuals or organizations that use water as a key input in production, understand their own water use, the catchment context in which they operate and the shared risk in terms of water governance, water balance, water quality and important water-related areas and engage in meaningful individual and collective actions that benefit people and nature.

The Integrated Water Resource Action Plan Programme spearheaded by the World Wildlife Fund seeks to create essential enabling conditions for effective water regulation and governance, sustainable land and natural resource use and sustainable development in the Lake Naivasha Basin. In collaboration with the Kenya Flower Council (KFC), WWF is implementing an activity that will increase sustainable production and good stewardship in Lake Naivasha Basin by adopting national watershed standards by WRMA and NEMA and certification protocols.

The standards require the farms to have a water use license as per laws of the land, monitor the quality of water discharged, have discharge emanating from irrigation recycled, use efficient methods of irrigation such as drip as opposed overhead and; have amount of nitrate discharged minimized. Also, effluent should be properly done and a farm water management policy maintained. Important water related areas in the farms include lake riparian, wetlands, water reservoirs, drainage channels and spray off site.The KFC Water Stewardship standard is a useful tool to improve water governance in Lake Naivasha Basin.

Studies in ASAL parts have focused on rainwater harvesting (Ondieki 1995, 2012) where the physico-chemical composition is susceptible to rapid changes of flow. Before launching a water harvesting project using rainwater harvesting systems, it is important to know the expected quality of harvested water. The harvesting process may involve sandy sub surface dams, roof catchments or rock catchments. Whearas the hydraulics of the process of retrieving water from ASAL areas into the collection systems is well known, the hydrochemical processes and processes of chemical transport for predicting quality of harvested water is not well established. This could be achieved through model approaches using coefficients of different chemicals found in ASAL catchments to predict chemical quality of harvested water. Generally, pollutants of interest have to be continuously monitored concurrent with the hydrological events to ensure proper calibration and validation of the models.

Investigations have been carried out seeking causes for the extreme fluctuations of the Rift valley lakes that have led to drying up of some such as Lake Elmentaita and flooding in some as recently observed in Lake Naivasha. The factors have been attributed to changing climatic conditions and land use cover changes. There have also been situations of abstraction and damming in the feeder streams and rivers to cater for horticultural activities. Further, the erosion of top soil along with nutrient transport would affect the water quality of the lakes with adverse ecohydrological implications which may also be reflected in economic losses from the fisheries for example.

Some reflections on water pollution challenges

Industrial waste is the most common source of water pollution and it increases yearly due to the growth of industries as most countries are getting industrialized. The development of urban areas is hardly controlled and informal settlements within urban conurbations lack sanitation and clean water. Heavy precipitation events pose pressure on urban and rural infrasture which often get worse with increased urbanization. This has been evidenced in Kenya's counties of Narok, Kisii and Nairobi among others. Urban centres are expanding immensely in Kenya and climate change intervention and adaptation strategies for storm water management are critical (Ondieki, 2013).

Does insurance play role in the climate change mitigation stratagies in our region yet? How can one isolate the climate change impacts for climate adaptation and mitigation strategies? What innovations in climate change adaptation would ensure job creation for the ever increasing vulnerable population in the region? To what extent has climate change science really informed policy in the agricultural sector? Kenya's renewable freshwater is derived from rainfall, surface water in rivers and lakes and groundwater. The scarcity aspect in our water resource is pegged to space time hydrological variability. By 2025, Kenya is projected to have a renewable freshwater supply of only 235 m^3/capita/annum.

Environmental degradation of terrestrial and aquatic systems causing flooding, pollution, reduced ground water recharge, and reduced stream base flow result in poverty levels. This is attributed to poor cultivation methods, deforestation, overgrazing and encroachment of the buffer zones on river riparians. Riparians could filter out pollutants; sediment and nutrients that get deposited within instead of in water. Buffer zones can also be created near farms and roads to prevent nutrients from traveling too far. The main cause of deterioration in water quality is lack of proper sanitation, unprotected river sites and high anthropogenic activities including direct and indirect disposal of the solid wastes, domestic and municipal sewage and agricultural run-off to the rivers both from urban and rural areas.

Investing in water storage could increase access to water supply capacity for the increasing population thereby help realize the country's Vision 2030 objectives. The opportunities to be exploited include; the potential of the fresh water resources, improved performance of the institutions such as WRMA, implemention of the strategic development plans taking benefit of the climate change initiatives, and; benefiting from global carbon trade as well as inputs from learned societies and established water quality standards.

In the Kenya ASALs the average access to safe water is estimated at below 40% compared to the national average of over 70%. Very few ASAL urban centres have sewerage systems and where they are, most are often blocked due to misuse and lack of proper maintenance. The unstable soils cause sagging during rainy periods thereby rendering limited pit latrine usage duration. The practices in the agricultural watersheds have implications on the water quality of the surface and ground water sources.

Conclusion

Increasing demands and declining water quality, growing vulnerability from floods and droughts, water borne diseases and; ecohydrological problems confront water resources management with challenges.

These need strategies for providing water of adequate quantity and quality and protecting man and the ecosystem from adverse impacts. Sustainable solutions that cater for increasing water demand for agriculture, industry, environment and urbanization have to be considered.

Appropriate mechanisms have to be provided for fostering the water quality management. The adoption of the watershed management plans provides promise for dealing with watershed challenges. Diffusion and adoption of sustainable watershed management practices requires coordinated inputs and appropriate partnerships. Sound watershed management practices could reduce point and non point source pollution. Prevention and reduction of eutrophication could be addresed through technologies, public participation, economic instruments and cooperation.

Research pertaining to all hydrological systems must be integrated into the overall planning and development for governments to realize Vision 2030. The hydrology and water quality of watersheds and urban centres and cities is critical. Pollution sources and the dynamics of the pollution loadings must be determined to enable pollution control and remediation measures. Timely action may save costly clean up of the river basins in future.

References

Alliance for Water Stewardship. (2014). *The AWS International Water Stewardship Standard.* International Standard Development Committee (ISDC): 2014 Alliance for Water Stewardship Version 1.0.

Gathenya J. M., C. Nduhiu, J. Mwangi & S. Murachia (2014):' Responsible Water Stewardship: A new approach to strengthen cooperation and water governance in Lake Naivasha basin'.Paper presented in the 2nd.Hydrological Society of Kenya (HSK) meeting, Kenya Water Institute (KEWI) Nairobi, Kenya 29th.to 30th.April 2014

Hepworth, N., Agol, D., Von-Lehr, S., & O'Grady, K. (2011). *Exploring the Value of Water Stewardship in Africa; Kenya Case Study.* Alliance for Water Stewardship/Marks & Spencer/ GIZ.

ISO. (14000). *Environmental management; the ISO 14000 family of International Standards.*

LVEMP (1995). Lake Victoria Environmental Management Project document. Governments of Kenya, Uganda and United Republic of Tanzania. Retrieved June 8, 2012, from http://water.worldbank.org/publications/kenya-tanzania-uganda-lake victoria-environmental-management-project

Ongwenyi, G. S., Kitheka, J. U and Nyangaga, J.M (1993). The impact of Hydrological and Land use processes on the quality of water in the Gucha catchment, South Western Kenya. Hydrology of the Warm Humid Regions; Proceedings of the Yokohama Symbosium, July 1993, IAHS Publ. no. 216, 79-85.

Ontumbi G., J. Obando and **C. Ondieki (2015)** The influence of Agricultural Activities on the Water Quality of the River Sosiani in Uasin Gishu County, Kenya. International Journal of Research in Agricultural Sciences Vol 2, Issue 1, ISSN(Online): 2348-3997).

Ondieki C. M. 1995 Field assessment of flood event suspended sediment transport from ephemeral streams in tropical semi- arid catchments.(Environmental Monitoring Assessment, EMAS 35: 43-54).

Ondieki C. M. (2012): Water Dependencies: Systems under Stress and Societal Responses. Hydrological Society of Kenya Conference Proceedings (Edited) Kenyatta University Press. 214 pp.. **ISBN: 978-9966-21-231-3.**

Ondieki C. M. (2013): Hydrology and Integrated Water Resource Management for Sustainable Watershed Management in Kenya. In H. Muga and K. Thomas (Eds). Cases on the Diffusion and Adoption of Sustainable Development Practices(pp 352-375). Hershey, PA. Information Science Reference. (http://www.igi-global.com/chapter/hydrology-integrated-water-resource-management/73300. **ISBN 978-1-4666-2842-7.**

United Nations. (2012). *World Water Development Report.* World Water Assessment Programme (WWAP).

WWF. (2012). *Shared Risk and Opportunity in Water Resources; Seeking a Sustainable future for Lake Naivasha.* Pegasys - Strategy and Development.